

DRAFT 11/12/20 G. Allen

PM Work Group Discussion Topics, 11/16/20 call on tunnel mixing issues.

I'd like to thank everyone for being willing to participate again in this workgroup process. In advance of our Monday 11/16 call at 3pm ET, this is a list of suggested discussion topics. Please send along any other ideas you would like to cover. The goal of this call is to come up with a list of potential dilution tunnel design modifications and critical design parameters that could be useful for improving tunnel PM mixing. These suggestions will be shared with EPA as they work towards possible 2023 revisions to the residential wood heat appliance NSPS.

1a. Assessment of ASTM as-is – could it have mixing issues despite very large Reynolds #s? <<The dilution tunnel diameter shall be sized such that the flow velocity as measured as shown in 9.3 and as established in 9.2.2 shall result in a minimum of 4.1 m/sec (800 ft/min)>> ASTM has a section labeled “Mixing” – the horizontal run between the hood and the down-section where sampling is done. However, there are no dimensions for that mixing section – no diameter, no length, no velocity, no residence time. Requiring this section to be larger might be part of a solution – a longer horizontal run with at least 12 in. diameter.

1b. Some EPA certified labs have tunnels with a 12 to 8 or 10 to 6 inch reducer after final elbow [non-compliant with ASTM] vs. before elbow as ASTM specifies. How much of a likely problem is this?

2. How might the ASTM tunnel be modified to improve mixing?

- (a). Is higher residence time / lower velocity in the final vertical section needed? Currently very short, ~0.5 seconds – do we need a minimum time spec?
- (b). Is the 90 deg bend before the straight sampling section an issue? Allow sets of 45 deg. [30 deg, 22 deg?] bends to get 90 deg? More of a curve than a bend?
- (c). Is 30 ft overall length ASTM limit necessary? Require a longer horizontal “mixing section” after the hood before the final bend?
- (d). Flow straighteners? They may get rid of cyclonic flow but will not necessarily ensure good mixing.
- (e). Baffles like 5G has? Other baffle designs? Concerns re: particle deposition.

3. Assuming the tunnel design is for 500 to 800 cfm, and one recommendation is a lower velocity / longer residence time / wider duct diameter [12 to 15”] for the straight vertical sampling section, pitot tubes can't be used for velocity measurements.

- tunnel flow measurement alternatives at lower velocities - sharp edged orifice?
- use hotwire anemometer for velocity traverses instead of pitot tubes?

4. How to evaluate mixing for PM?

- (a). Use inert gas [CO]? Paired [dichot] TEOMs?
- (b). What is the worst case mixing scenario re: tunnel DF / tunnel flows? Should labs be constrained to tunnel flows used to evaluate mixing?
- (c). Should verification of mixing be required for lab EPA certification?

5. Use a multi-port sample probe? This is done for gases – samples across a horizontal range within the tunnel to minimize possible horizontal heterogeneity. Requires uniform velocity across the range.

Phil Hopke suggested these papers might inform potential issues with a 90 deg. bend just upstream of the downward vertical section used for sampling, and suggested that CFD might be a useful tool to evaluate tunnel performance in general. If you would like a copy of any of these, please let me know.

Cong-A model for evaluating the particle penetration efficiency in a ninety-degree bend with a circular-cross section in laminar and turbulent flow regions_PowderTech2017 [HYPERLINK "<http://dx.doi.org/10.1016/j.powtec.2016.10.074>"]

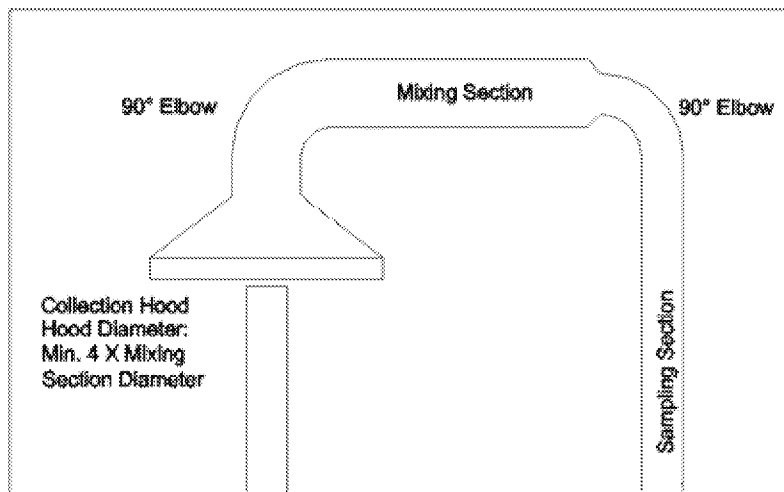
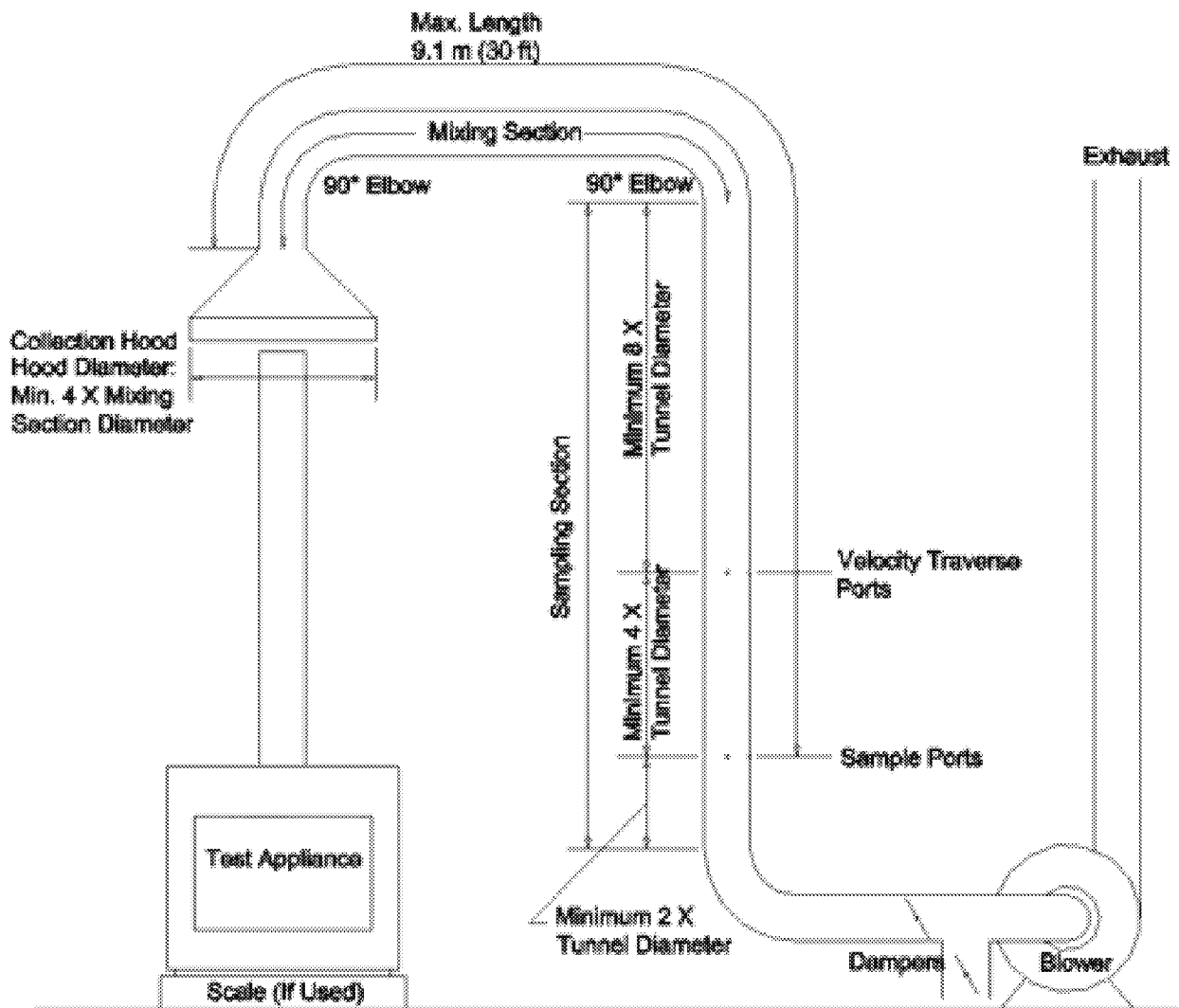
Noorani-Particle Velocity and Acceleration in Turbulent Bent Pipe Flows_FlowTurbulenceCombust2015 [HYPERLINK "<http://dx.doi.org/10.1007/s10494-015-9638-9>"]

Peters-Particle Deposition in Industrial Duct Bends_AnnalsOccupationalHygiene2004 [HYPERLINK "<http://dx.doi.org/10.1093/annhyg/meh031>"] [open access]

Hellström -Turbulent pipe flow downstream of a 90 deg bend_J.FluidMech.2013 [HYPERLINK "<http://dx.doi.org/10.1017/jfm.2013.534>"]

McFarland-Aerosol Deposition in Bends with Turbulent Flow_EST1997 [HYPERLINK "<https://pubs.acs.org/doi/abs/10.1021/es960975c>"] [open access]

ASTM 2515 tunnel diagram:



Example of a non-compliant ASTM2515 tunnel from a certified lab:

